WARDEN Proposers’ Day Intro

Mark Rosker, Director DARPA MTO

WARDEN Proposers’ Day

03/05/2021

DARPA

C4ISR

Electronic Warfare

Directed Energy

MTO
MICROSYSTEMS TECHNOLOGY OFFICE

MTO's core mission is the development of **high-performance, intelligent microsystems and next-generation components** to enable dominance in national security **C4ISR, EW, and DE applications**

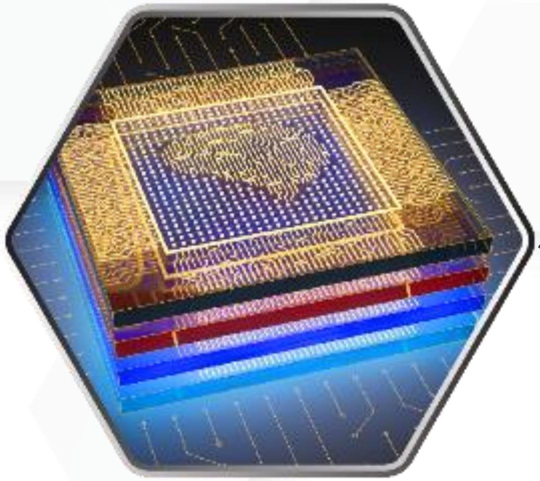
The **effectiveness, survivability, and lethality** of these systems depend critically on microsystems

(U) C4ISR: Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance

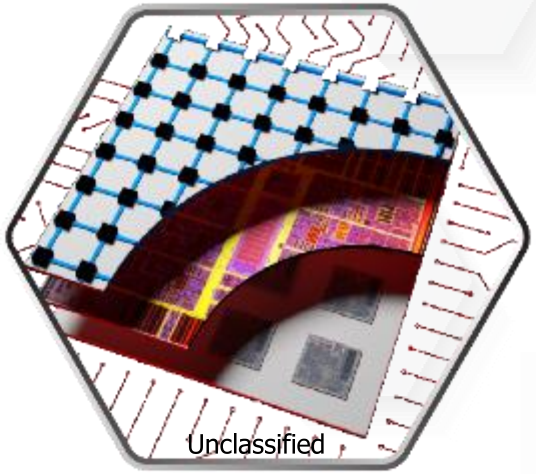
MTO
MICROSYSTEMS TECHNOLOGY OFFICE

DARPA

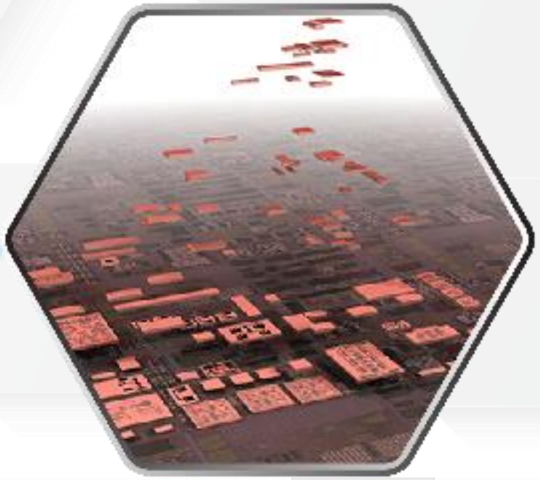
Embedded Microsystem Intelligence / Localized Processing



Microsystem Integration for Functional Density & Security

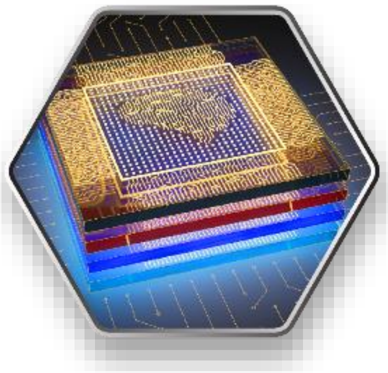


Next Gen Front-End Technologies for Electromagnetic Spectrum Dominance



Disruptive Defense Microsystem Applications

Technology Focus Areas

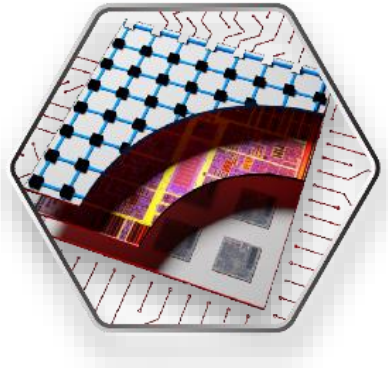


Embedded Microsystem Intelligence / Localized Processing

- Increasing information processing density & efficiency
- Making decisions at the edge faster
- Reducing the glut of digitized sensor data

Next Gen Front-End Technologies for Electromagnetic Spectrum Dominance

- Reducing SWaP-C of front-end elements
- Increasing tactical range
- Enabling robust operation in congested spectrum



Microsystem Integration For Functional Density & Security

- Overcoming the inherent throughput limits of 2D electronics
- Mitigating the skyrocketing costs of electronics design
- Overcoming security threats across the entire hardware lifecycle

Disruptive Defense Microsystem Applications

- Revolutionizing communications (5G and beyond)
- Reducing latency in EW
- Generating / directing high power radiation
- Delivering accurate position and timing w/o GPS

C4ISR: Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance

Disruptive Defense Microsystem Applications

- **Revolutionizing communications (5G and beyond)**
- **Reducing latency in EW**
- **Generating / directing high power radiation**
- **Delivering accurate position and timing without GPS**

(U) Disruptive Defense Microsystems Applications: Key Challenges

Revolutionizing communications (5G and beyond)

Problem: Ensuring network availability and security

Medium.com

Potential Approaches

- Digital arrays
- Low power element-level beamforming
- Advanced techniques for secure comms

Reducing latency in EW

Problem: Adaptive threats challenge ability to detect and counter

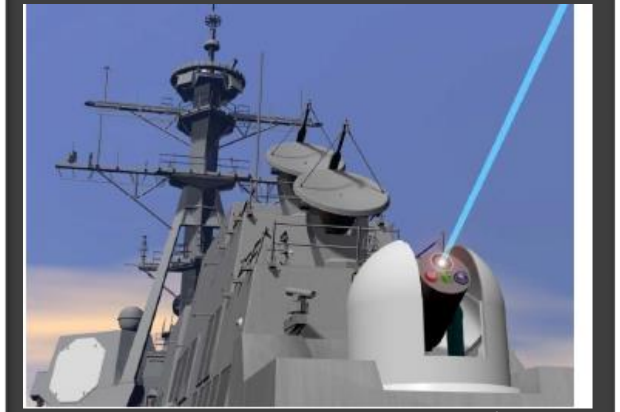
Navalnews.com

Potential Approaches

- Neural networks for RF signal recognition
- Embedded machine learning for cognitive EW systems

Generating / directing high power radiation

Problem: Advanced threats require high power countermeasures



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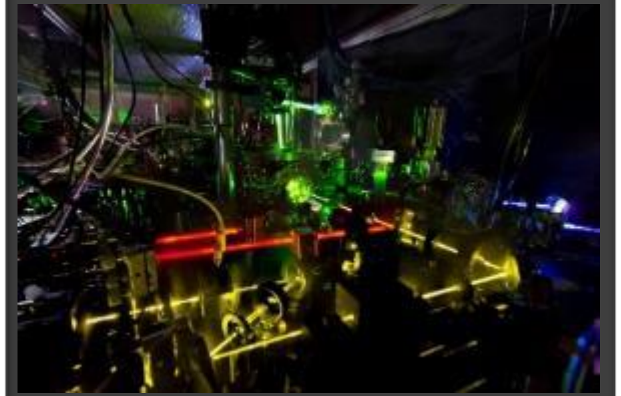
Potential Approaches

- Ultra-efficient, high power laser diodes
- Compact, high power laser arrays
- High power microwave systems

Delivering accurate position and timing w/o GPS

Problem: Low SWaP-C solutions required for GPS-denied environments



Potential Approaches

- Modern atomic physics for low SWaP clocks
- Advanced MEMS for inertial guidance
- Integrated photonic chips for clocks / gyros

(U) Disruptive Defense Microsystems Applications: Key Challenges

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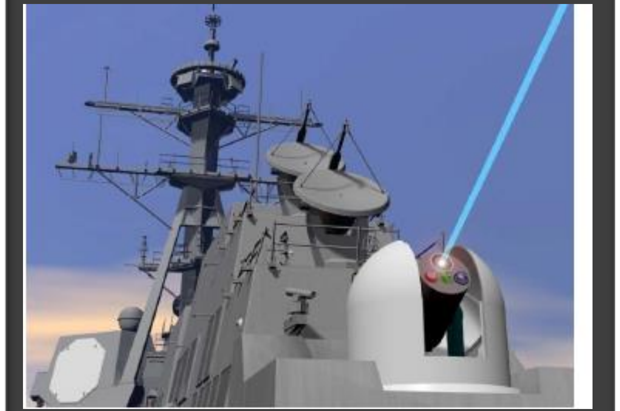

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WARDEN Proposers’ Day Agenda

Time	Event	Presenter
12:30	**Login**	
13:00	Welcome and Opening Remarks	Mark Rosker DARPA MTO Director
13:15	WARDEN Overview and Program Structure	David Abe DARPA MTO Program Manager
14:15	**Break**	
14:30	WARDEN Security	Ron Baxter DARPA Security & Intelligence Directorate
14:45	Contracting with DARPA	Michael Blackstone DARPA Contracts Management
15:15	DARPA Embedded Entrepreneurship Initiative	Kacy Gerst DARPA Embedded Entrepreneurship Initiative
15:30	Q&A / Discussion	
16:00	Adjourn	

Waveform Agile Radio-frequency Directed ENergy (WARDEN)

David K. Abe, Program Manager DARPA MTO

WARDEN will develop agile waveform technology to increase the range and lethality of HPM back-door attack

WARDEN Proposers' Day

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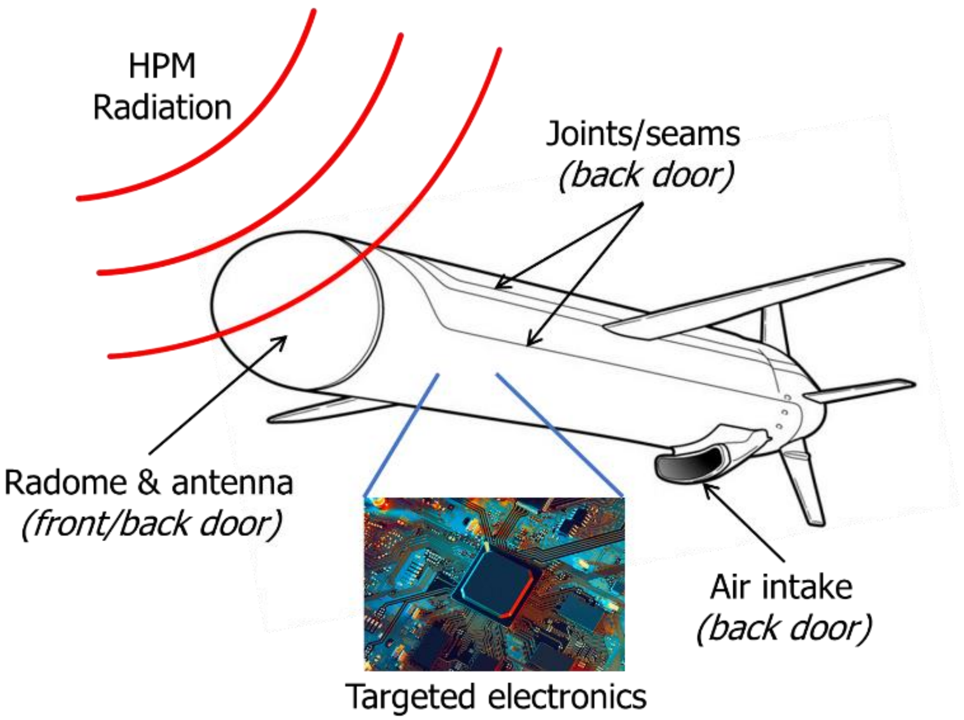
Background: High Power Microwave (HPM) Technology

High Power Microwave Operational Concept



Features:

- Non-kinetic and non-lethal
- Persistent effects over a wide area with large standoff distances
- Speed of light engagement with a deep magazine
- Scalable effects to limit collateral damage
- Operation in adverse environments (i.e., fog and dust)

Principal Methods of Attack:

- *Front door* : Electromagnetic (EM) radiation enters into the target via intentional ports such as antennas

- *Back door* : EM radiation enters via unintentional ports such as seams, cable entry points, and access panels

HPM Systems Today

Applications include:

- Counter-unmanned aerial systems
- Vehicle and surface vessel disruption
- Electronic strike (counter-C4ISR)
- Guided missile defense

Current systems are oscillator-based

Limitations of the current state-of-the-art:

- Narrow bandwidth (coupling efficiency)
- Maximum peak output power (range)
- Phenomenological approach to effects

https://www.kirtland.af.mil/Portals/52/documents/HPM.pdf?ver=2016-12-19-170711-837

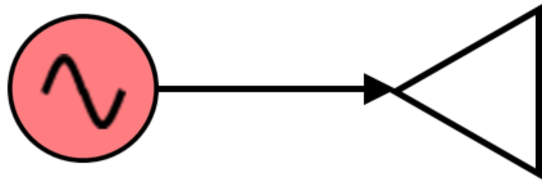
AFRL CHAMP (electronic strike)
Counter-electronics HPM
Advanced Missile Project

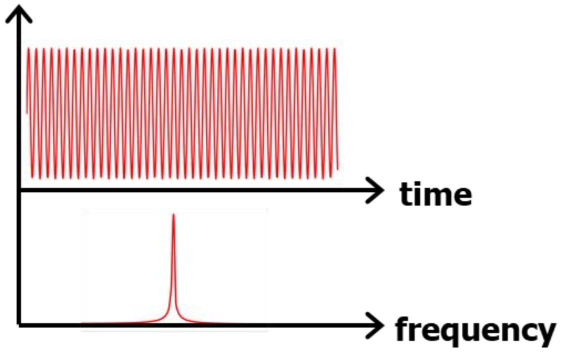
https://www.wpafb.af.mil/News/Article-Display/Article/1969142/enemy-drone-operators-may-soon-face-the-power-of-thor/

AFRL THOR (CUAS)
Tactical High Power
Operational Responder

HPM Current Art vs. WARDEN

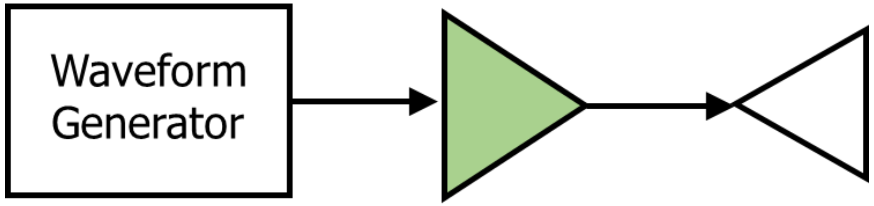
Current Art: Single system performs a single mission

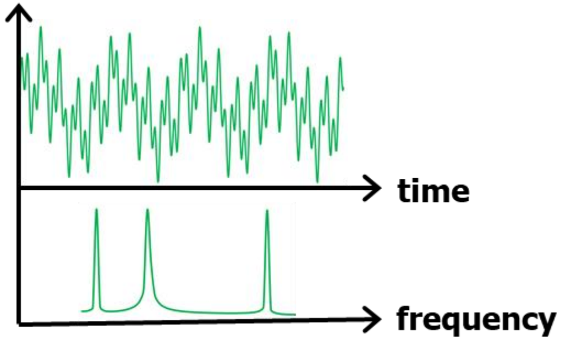




- Narrowband and lacking tunability to exploit target vulnerability
- Can only be optimized for a narrow set of target parameters
- **Cannot** be power combined

WARDEN: Systems can be scalable and effective against multiple target types





- Broadband supporting complex waveforms to produce maximum effects on electronics
- Waveforms can be optimized for a range of targets and missions
- **Can** be power combined

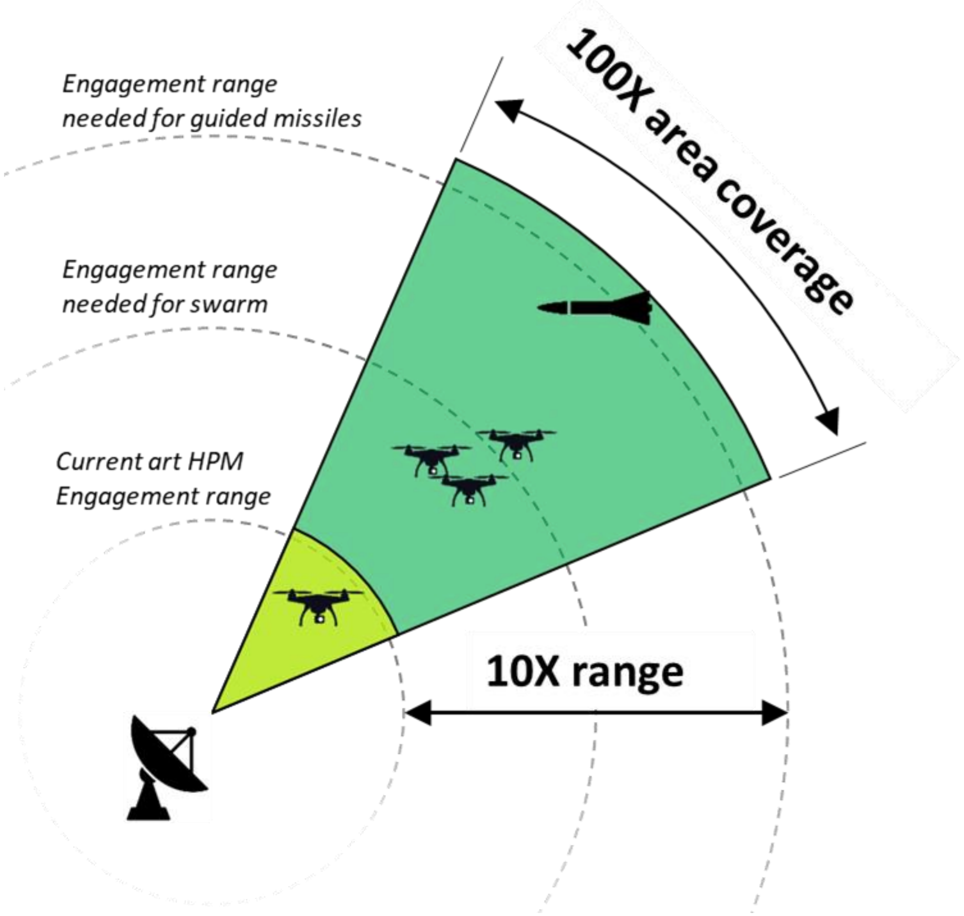
WARDEN will create enabling technology to extend range and minimize the RF power required to produce effects

Why is waveform agility important?

- Maximize energy coupling into the target
- Waveform techniques can be optimized to exploit target vulnerabilities

WARDEN Goals and Approach

Program goal: Develop hardware, theory, and computational models to extend the range and effectiveness of HPM systems for back-door attack



WARDEN will address three key technical challenges:

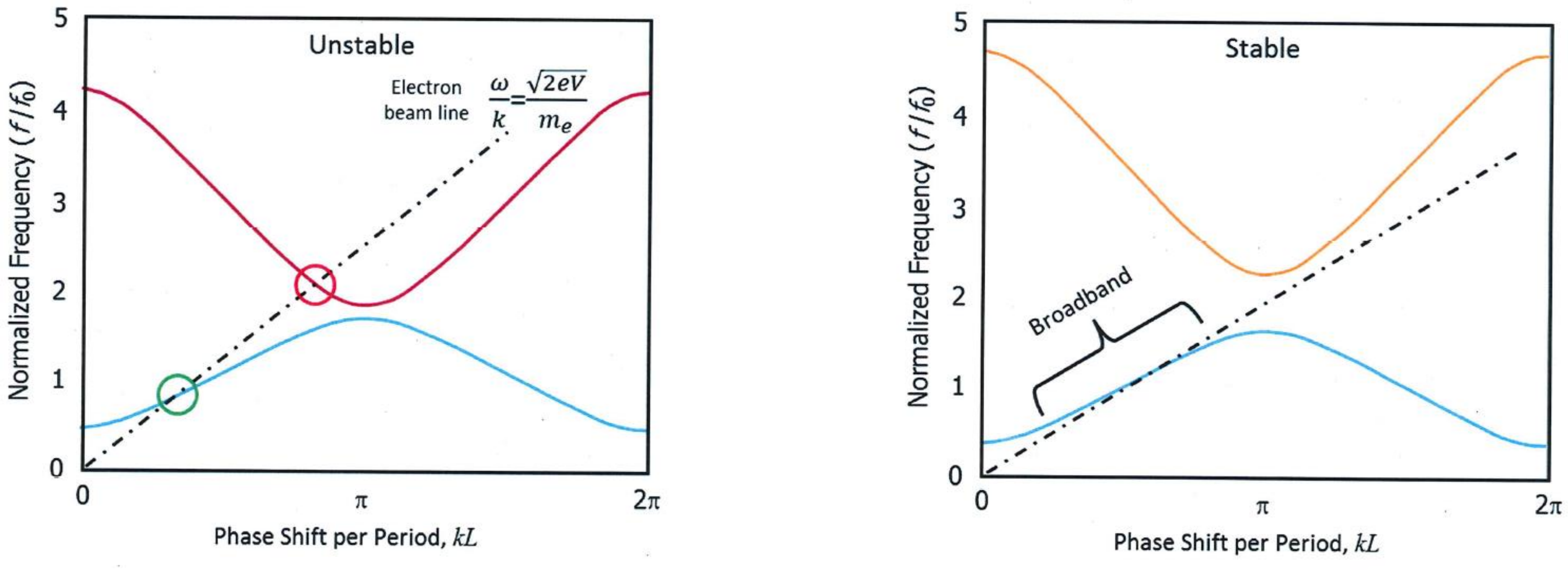
- Stable, high power, broadband amplification
- Theory and computational tools to predict EM coupling into complex enclosures
- Predictive tools and agile waveform techniques enabling the identification and exploitation of electronic system vulnerabilities

Challenge 1: Stable, Broadband HPM Amplification

- Vacuum electronic amplifiers produce amplification by synchronizing the velocity of the electron beam with the phase velocity of an electromagnetic wave propagating in a periodic interaction structure

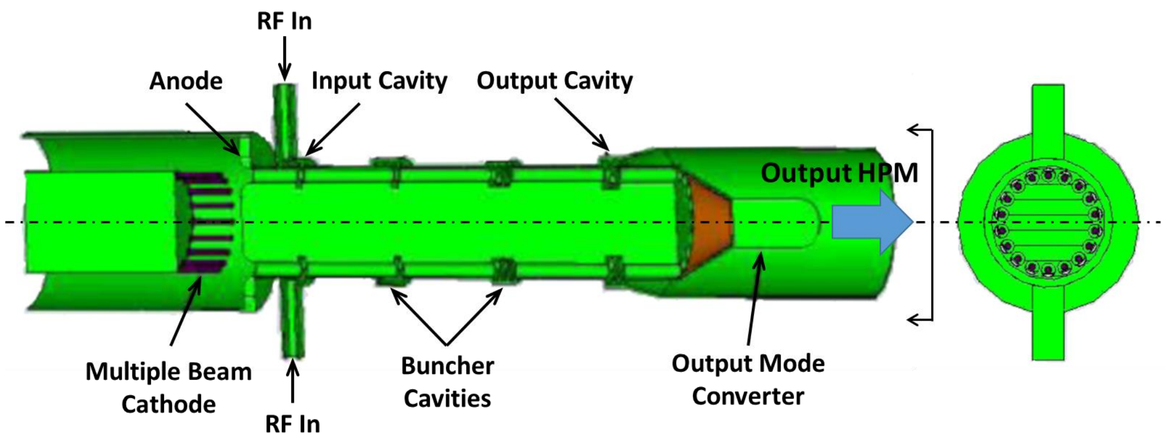
- The challenge is the co-design of the electron beam parameters, the interaction structure characteristics, and the interface components to maximize power and bandwidth and avoid oscillation

Dispersion plots of an electron beam propagating in a periodic structure



Approach: Electromagnetic traveling-wave amplification structures

Narrowband, cavity-based amplifier



Z. Liu et al., "Investigation of an X-band long pulse high gain multi-beam relativistic klystron amplifier," IEEE Trans. on Electron Dev. 66(1), Jan. 2019

• Peak power	2.2 GW
• Center frequency	9.4 GHz
• Gain	~46 dB
• Fractional bandwidth	<<1%

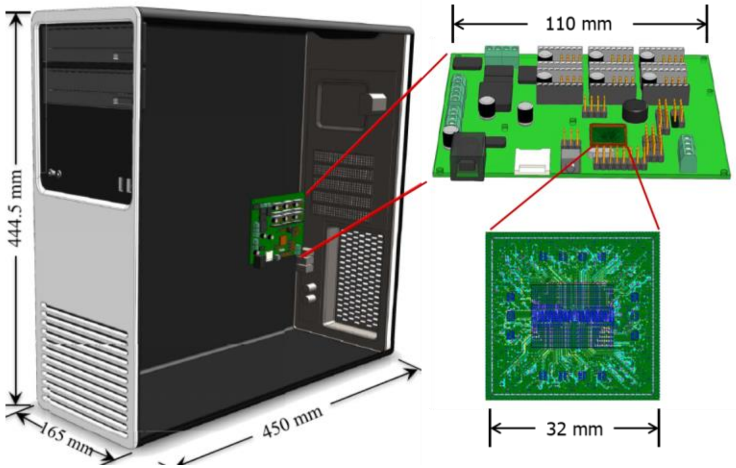
Insights

- Electromagnetic traveling-wave structures can support up to 100x bandwidths compared with current art resonant cavity-based structures
- Aperiodicity and asymmetry in circuit design can be used to enhance amplifier performance and stability (3D design challenge)
- DoD-developed 3D simulation tools provide unprecedented capabilities to analyze VE device performance and identify and mitigate the onset of instabilities

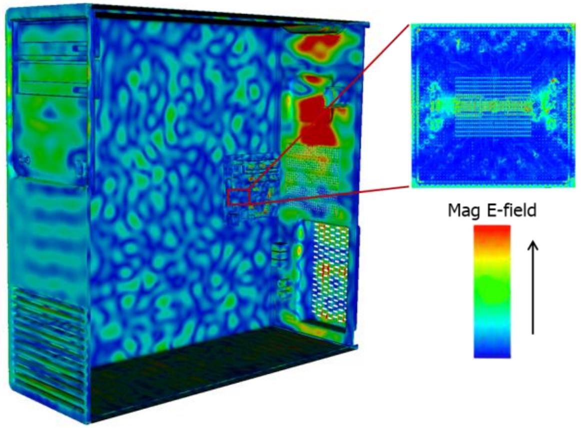
Challenge 2: Rapid Simulation of EM Coupling into Complex Enclosures

- Current deterministic modeling approaches using finite element or finite difference discretizations require a detailed knowledge of both external and internal features
- Computational meshes are enormous and require long runtimes for convergence
- Many runs are required to simulate an ensemble of configurations and frequencies

Example: Package level deterministic simulation of electric fields in a desktop computer



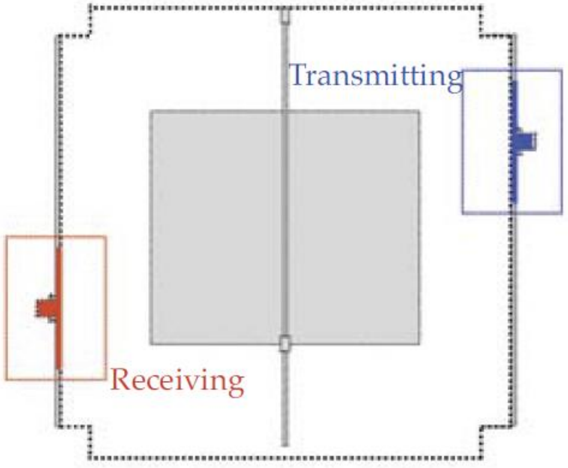
Single Run Computational Statistics	
Matrix dimension (# of unknowns)	75×10^6
Wavelength (frequency)	3 cm (10 GHz)
Number of iterations	8
Simulation time	2 hours (HPC)
# of compute cores	2,944



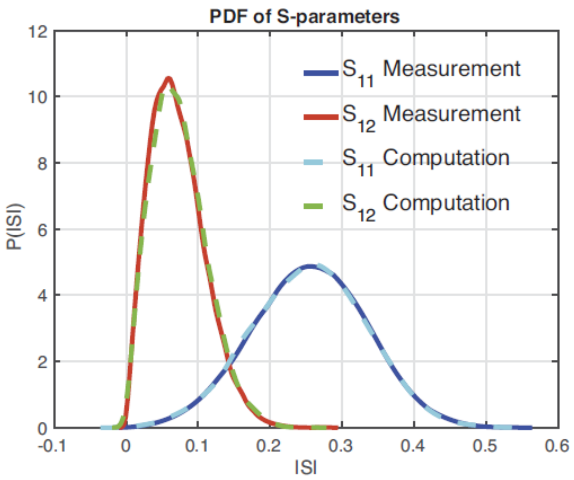
Z. Peng et al., “High-fidelity, high-performance computational algorithms for intrasystem electromagnet interference analysis of ICs and electronics,” IEEE Trans. Components, Packaging & Manufacturing Tech. 7(5), May 2017.

Approach: Rapid Assessment & Numerical Generation of EM Response (RANGER)

Hybrid Deterministic and Stochastic Model



Computational & Experimental Set-up



Computed & Measured Probability Density Function

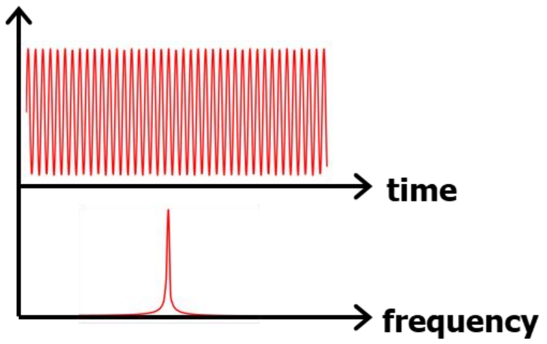
S. Lin et al, "A novel statistical method for the electromagnetic coupling to electronics inside enclosures," IEEE Int. Symp. on EM Compatibility, Signal & Power Integrity, 2019

Insights

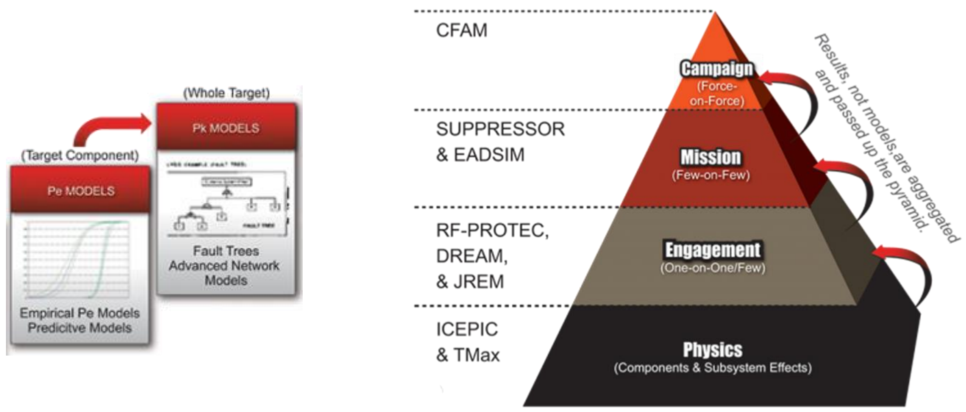
- For example, new statistical approaches require only an approximate knowledge of the target's external and internal features
- Simulations predict the statistical distribution of EM fields and voltages over a range of frequencies
- Computation take minutes on a desktop computer as opposed to hours on an HPC network

Challenge 3: HPM Effects on Electronics

- Current art narrowband waveforms must rely on high power to overcome EM coupling inefficiencies
- Absent a suitable amplifier technology, there has been sparse R&D in broadband waveforms for HPM use
- We lack predictive modeling capabilities to optimize waveforms for optimum effects on electronics
- Current art HPM models based on laboratory measured data have limited predictive capabilities

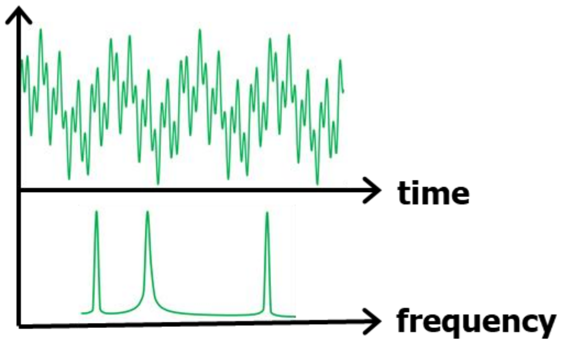


DoD Modeling Pyramid

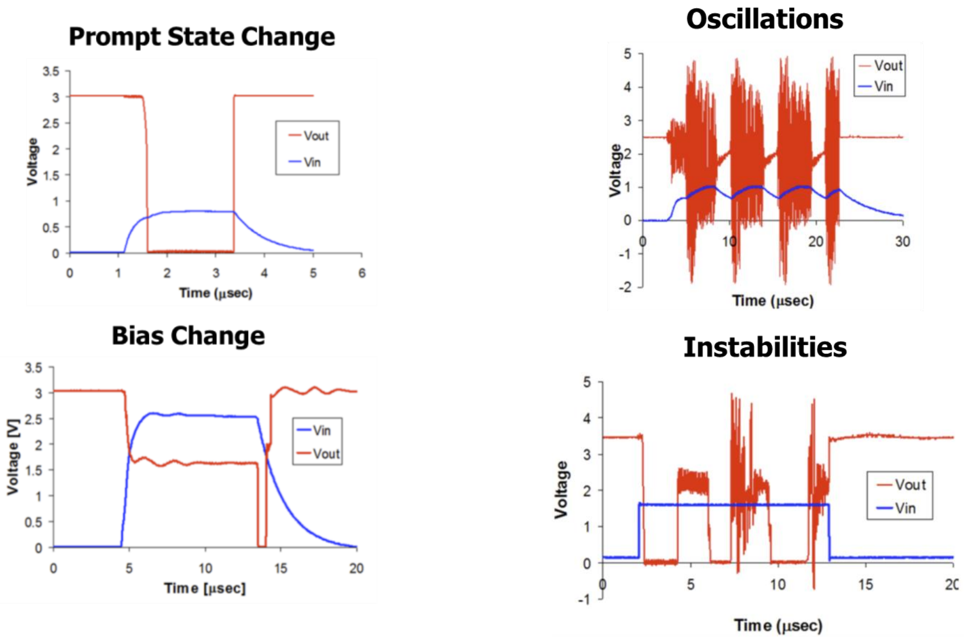


J. Tatum, "High-power microwave directed energy weapons: A model and simulation toolbox," DSIAC Journal 1(2), 2014

Approach: Agile Waveform Development



Examples of upset in primitive circuit elements



M.A. Holloway, "Overview of HPM Effects in Electronics," LANL Report LA-UR-12-21858, 2012

Insights

- Frequency, amplitude, and pulse width modulations can increase the susceptibility of electronic systems to disruption by EM radiation
- New methods to experimentally characterize the responses of basic components, PCBs, and sub-systems
- Leverage recent modeling approaches and extend them to broader classes of electronic targets

WARDEN Program Metrics

	Metric	Phase 1 (12 months)	Phase 2 (24 months)	Phase 3 (12 months)
TA1	Refer to WARDEN classified addendum			
TA2	Model agreement [%] (with simulated or measured data)	>50	>80	>80
	Code runtime [minutes, non-HPC]	---	<60	<30
TA3	Refer to WARDEN classified addendum			

WARDEN Program Structure

TA1 (SECRET)	**HPM Traveling-wave Amplifier** *Deliver RF power to the target with waveform agility*
TA2 (UNCLASSIFIED)	**Rapid Assessment & Numerical Generation of EM Response (RANGER)** *Rapid prediction of the spatio-temporal distribution of electric fields*
TA3 (SECRET)	**Agile Waveform Development** *Create disruptive effects on target electronics*

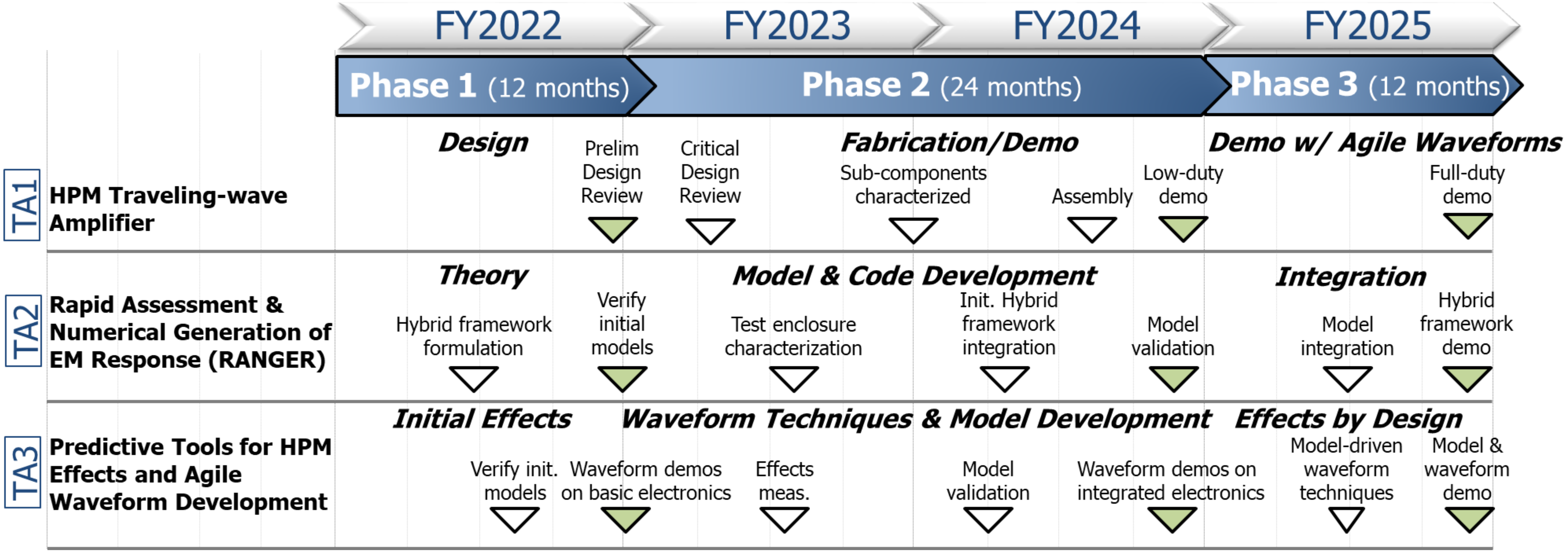
Gov't Independent Verification & Validation

- Disseminate effects data. test parameters & target sets
- Review designs, models, & theory
- Disseminate GFP modeling tools

- Amplifier demonstration at performer facility
- V&V coupling and effects models
- V&V predictive tools against known targets

- Final amplifier V&V
- Support transition of models to DoD tools
- Curate database of effects & waveform techniques

Program Schedule



WARDEN Program Proposal Guidelines

- Proposers should not propose to more than one Technical Area in a single proposal.

  Proposers who wish to submit to more than one TA must submit a separate full proposal for each. Tasks that would be duplicated in the effort if both TAs were awarded must be called out explicitly.
- WARDEN TA1 performers should expect to interact with TA3 performers through Associate Contractor Agreements (ACAs) to receive waveforms developed within TA3 in a common non-proprietary format for use with the amplifiers developed in TA1.
- It is intended that ACAs be established between TA1 and TA3 performers prior to contract award.

WARDEN Program Proposal Guidelines

- Proposals to TA1 and TA3 of WARDEN are expected to be classified at the COLLATERAL SECRET level. Therefore, performers will require collateral SECRET clearances and secure communications in order to support classified development. **Please reference BAA Attachment 3 "Security Classification Guide and Classified Addendum Request Form" for additional information.**
- Proposers that meet the personnel security requirements and the appropriate facility clearance status/level (DCSA Certified & Accredited Facility), along with possessing a background in high-power vacuum amplifiers (TA1) or electromagnetic effects on electronics and waveform techniques (TA3), may request the SCG and Classified BAA Addendum. If you do not meet the security requirements, it is suggested you look into teaming with other proposers who meet the requirements.
- Proposers should include with their proposal any proposed solution(s) to program security requirements unique to this program.
- Prior to submitting a classified proposal, proposers must notify security by April 9, 2021 at 5:00 PM (ET). An email to HR001121S0017@darpa.mil is sufficient.

WARDEN Program Proposal Guidelines

- Proposals shall consist of two volumes: Volume I – Technical and Management Proposal (3 sections), and Volume II – Cost Proposal (4 sections).
- A summary slide of the proposed effort, in PowerPoint format using the provided Proposal Summary Chart template, should be submitted with the proposal.
- Proposers should provide a technical and programmatic strategy that conforms to the entire program schedule and presents an aggressive plan to fully address all program goals, metrics, milestones, and deliverables.
- Proposers are <u>required</u> to provide the [proposal] cost breakdown as an editable MS Excel spreadsheet, inclusive of calculations formulae, with tabs (material, travel, ODC's) provided as necessary.
- Proposers shall identify in their proposal any pre-existing technical data or commercial/non-commercial software that they will deliver to the Government with less than unlimited rights. Proposers should indicate in their proposal whether they believe the scope of the research included in their proposal is fundamental or not.
- To avoid missing deadlines, proposers should submit their proposals in advance of the final proposal due date with sufficient time to receive confirmations and correct any errors in the submission process.

Key Dates

❑ February 26, 2021		WARDEN BAA publication
❑ March 05, 2021	1300-1600 ET	WARDEN Proposers' Day
❑ March 25, 2021	1700 ET	Last day to request WARDEN Security Classification Guide and Classified BAA Addendum
❑ April 07, 2021	1700 ET	Frequently Asked Questions deadline
❑ April 09, 2021	1700 ET	Deadline to notify DARPA Security Team of intent to submit classified proposals
❑ April 16, 2021	1400 ET	Proposal due date

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